LISTING OF THE CLAIMS

1. (Original) A method for detecting an abnormal combustion condition in a spark ignited combustion chamber of a reciprocating engine having an exhaust gas recirculation (EGR) valve to recirculate exhaust gas to obtain a desired level of NOx emission, the abnormal combustion condition comprising one of a misfire and a knock, the method comprising the steps of:

detecting the variation of an ionization signal that changes with respect to an engine parameter over a combustion event of the reciprocating engine;

associating a floating bounded space with the ionization signal;

determining if a portion of the ionization signal is within the floating bounded space; and

adjusting an output of the EGR valve if the portion of the ionization signal is within the floating bounded space.

2. (Original) The method of claim 1 further comprising the step of detecting the ionization signal wherein the engine is operating with an air to fuel ratio corresponding to a λ greater than 1.4.

3. (Original) The method of claim 1 wherein the abnormal combustion condition is a misfire and the step of determining if the portion of the ionization signal is within the floating bounded space comprises the step of determining if the portion of the ionization signal remains within the floating bounded space for an extended interval corresponding to the duration of the floating bounded space.

4. (Original) The method of claim 3 further comprising the step of confirming that the misfire has occurred by checking a secondary sensor.

5. (Original) The method of claim 1 wherein the abnormal combustion condition is knock and the step of determining if the portion of the ionization signal is within the floating

bounded space comprises the step of determining if any portion of the ionization signal is within the floating bounded space.

6. (Original) The method of claim 5 wherein the floating bounded space comprises a first portion and a second portion and the step of determining if the portion of the ionization signal is within the floating bounded space comprises the step of determining if any portion of the ionization signal is within one of the first portion and the second portion.

7. (Original) The method of claim 6 wherein the step of providing the indication comprises the step of providing one of an indication of incipient knock if said any portion of the ionization signal is within the first portion and not the second portion and an indication of severe knock if said any portion of the ionization signal is within the second portion.

8. (Original) The method of claim 1 further comprising the step of adjusting at least one of a position and size of the floating bounded space as a function of engine operating conditions, the engine operating conditions including at least one of an engine speed, an engine load, and a desired percent EGR.

9. (Original) The method of claim 1 further comprising the step of adjusting a combustion parameter if the abnormal combustion condition has been detected.

10. (Original) The method of claim 9 wherein the abnormal engine condition is misfire and the step of adjusting the combustion parameter comprises at least one of adjusting the ignition timing and reducing the percent EGR.

11. (Original) The method of claim 9 wherein the abnormal engine condition is knock and the step of adjusting the combustion parameter comprises at least one of retarding the ignition timing and adjusting the percent EGR.

12. (Original) A method of identifying abnormal combustion cycles in a reciprocating engine having an exhaust gas recirculation (EGR) valve to recirculate exhaust

gas to obtain a desired level of NOx emission, the abnormal combustion cycles being characterized by an abnormal event, the method comprising the steps of:

a) collecting ionization signals relating ionization current to engine rotational position for a plurality of successive combustion cycles of the reciprocating engine, some of the combustion cycles being normal, and others of the combustion cycles being characterized by the abnormal event;

b) identifying a characteristic of the ionization signal for the abnormal combustion cycles which distinguishes from the ionization signal for the normal combustion cycles;

c) associating at least one floating bounded space with the ionization signals and adjusting the position and size of the floating bounded space so that the floating bounded space captures the characteristic which distinguishes the abnormal combustion cycles; and

d) testing subsequently generated ionization signals with the floating bounded space to distinguish between normal and abnormal combustion cycles of the reciprocating engine.

13. (Original) The method of claim 12 wherein the engine is operating with an air to fuel ratio corresponding to a λ greater than 1.4, the method further comprising the step of detecting the ionization signals.

14. (Original) The method of claim 12 further including the steps of identifying a second characteristic of the ionization signal which distinguishes a second abnormal event from both the normal signal and the abnormal event, and repeating steps c-d for the second abnormal event.

15. (Original) The method of claim 14 wherein the abnormal event is incipient knock and the second abnormal event is severe knock.

16. (Original) The method of claim 12 wherein the abnormal event is one of misfire and knock.

17. (Original) The method of claim 12 further comprising the step of providing an indication if an abnormal event is detected.

18. (Original) The method of claim 12 further comprising the step of adjusting an amount of exhaust gas recirculating if an abnormal event is detected.

19. (Original) The method of claim 12 wherein the step of adjusting the position and size of the floating bounded space includes adjusting at least one of the position and the size of the floating bounded space as a function of engine operating conditions, the engine operating conditions including at least one of an engine speed, an engine load, and a desired amount of exhaust gas recirculating in the reciprocating engine.

20. (Original) The method of claim 12 wherein the abnormal event is misfire and the step of associating at least one floating bounded space with the ionization signals and adjusting the position and size of the floating bounded space comprises the steps of :

establishing a start engine rotational position;

determining a duration of the floating bounded space;

determining a lowest ionization signal level over the duration; and

adjusting the position of the floating bounded space at the start engine rotational position to the lowest ionization signal level.

21. (Original) The method of claim 12 further comprising the step of segregating the ionization signals into ionization signals for normal combustion cycles and ionization signals for abnormal combustion cycles based upon an engine parameter that can be used to identify whether the combustion cycle associated with an ionization signal is an abnormal combustion cycle or a normal combustion cycle.

22. (Original) The method of claim 21 wherein the engine parameter is indicated mean effective pressure.

23. (Original) The method of claim 21 wherein the engine parameter is the peak of the derivative of cylinder pressure.

24. (Original) A method to detect an abnormal combustion condition of a reciprocating engine having an exhaust gas recirculation (EGR) valve to recirculate exhaust gas to obtain a desired level of NOx emission, the method comprising the steps of:

associating a floating bounded space with an ionization signal such that the floating bounded space captures a characteristic of the ionization signal which distinguishes the abnormal combustion condition from a normal combustion condition for an engine operating ;

detecting the variation of an ionization signal with respect to an engine parameter over a combustion event; and

adjusting the amount of exhaust gas recirculating if a portion of the ionization signal falls within the floating bounded space.

25. (Original) The method of claim 24 wherein the engine is operating with an air to fuel ratio corresponding to a λ greater than 1.4, the method further comprising the step of detecting the ionization signal.

26. (Original) The method of claim 24 wherein the abnormal combustion condition is a misfire and the step of adjusting the amount of exhaust gas recirculating comprises the step of reducing the amount of exhaust gas recirculating if the portion of the ionization signal remains within the floating bounded space for an extended interval corresponding to the duration of the floating bounded space.

27. (Original) The method of claim 24 wherein the abnormal combustion condition is knock and the step of adjusting the amount of exhaust gas recirculating comprises the step of increasing the amount of exhaust gas recirculating if any portion of the ionization signal is within the floating bounded space.

28. (Original) The method of claim 24 wherein the floating bounded space comprises a first portion and a second portion, and the step of adjusting the amount of exhaust gas recirculating comprises the step of increasing the amount of exhaust gas recirculatingby a larger amount if any portion of the ionization signal is within the second portion than the

amount increased when any portion of the ionization signal is within the first portion and outside the second portion.

29. (Original) A method to determine a floating bounded space and a starting point for the floating bounded space used to determine an abnormal combustion condition comprising the steps of:

receiving a set of ionization signals that change with respect to an engine parameter over a combustion event, the set having ionization signals corresponding to normal combustion conditions and ionization signals corresponding to at least one abnormal combustion condition for an engine operating with an exhaust gas recirculation valve to recirculate exhaust gas to obtain a desired level of NOx emission ;

adjusting the starting point and a size of the floating bounded space such that selected portions of the ionization signals corresponding to the at least one abnormal combustion condition reliably fall within the floating bounded space and the ionization signals corresponding to normal combustion conditions reliably fall outside the floating bounded space.

30. (Original) The method of claim 29 wherein the at least one abnormal combustion condition is a misfire and the step of adjusting the starting point and the size comprises the step of adjusting at least one of the starting point and the region such that the selected portion of the ionization signals corresponding to the at least one abnormal combustion condition reliably remains within the floating bounded space for an extended interval corresponding to the duration of the floating bounded space and the ionization signals corresponding to the normal combustion conditions reliably fall outside of the floating bounded space.

31. (Original) The method of claim 29 wherein the at least one abnormal combustion condition is a knock, the selected portion of the ionization signal is any portion of the ionization signal and the step of adjusting the at least one of the starting point and the region comprises the step of adjusting at least one of the starting point and the size such that the selected portion of the ionization signals corresponding to the at least one abnormal combustion condition reliably falls within the floating bounded space and the ionization

signals corresponding to the normal combustion conditions reliably fall outside of the floating bounded space.

32. (Original) The method of claim 29 wherein the floating bounded space has an upper portion and a lower portion, the knock is an incipient knock and the step of adjusting the at least one of the starting point and the size comprises the step of adjusting at least one of the starting point and the size such that selected portion of the ionization signals corresponding to the at least one abnormal combustion condition reliably falls within the lower portion and outside the upper portion and the ionization signals corresponding to the normal combustion conditions reliably fall outside the floating bounded space.

33. (Original) The method of claim 29 wherein the floating bounded space has an upper portion and a lower portion, the knock is an severe knock and the step of adjusting the at least one of the starting point and the region comprises the step of adjusting at least one of the starting point and the region such that the selected portion of the ionization signals corresponding to the at least one abnormal combustion condition reliably falls within the upper portion and the ionization signals corresponding to the normal combustion conditions reliably fall outside the upper portion.

34. (Original) The method of claim 29 wherein the floating bounded space is a floating box.

35. (Original) The method of claim 29 wherein the step of adjusting the starting point and the size of the floating bounded space includes adjusting at least one of the starting point and the size of the floating bounded space as a function of engine operating conditions, the engine operating conditions including at least one of an engine speed, an engine load, and a desired percent of exhaust gas recirculating.

36. (Original) A method to detect an abnormal combustion condition of a reciprocating engine having an exhaust gas recirculation valve to recirculate exhaust gas to obtain a desired level of NOx emission, the method comprising the steps of:

associating a floating bounded space with an ionization signal such that the floating bounded space captures a characteristic of the ionization signal which distinguishes the abnormal combustion condition from a normal combustion condition for an engine;

detecting the variation of an ionization signal with respect to an engine parameter over a combustion event;

detecting if a portion of the ionization signal falls within the floating bounded space; and

adjusting an amount of exhaust gas recirculating if the portion of the ionization signal falls within the floating bounded space.

37. (Original) The method of claim 36 further comprising the step of providing an indication that the abnormal combustion condition has been detected if the portion of the ionization signal falls within the floating bounded space.

38. (Original) The method of claim 36 wherein the abnormal engine condition is misfire and the step of adjusting the combustion parameter comprises at least one of adjusting the ignition timing and reducing the amount of exhaust gas recirculating.

39. (Original) The method of claim 36 wherein the abnormal engine condition is knock and the step of adjusting the combustion parameter comprises at least one of retarding the ignition timing and increasing the amount of exhaust gas recirculating.